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(54) Title: METHOD AND APPARATUS FOR THE PRODUCTION OF A STRUCTURE BY FOCUSED LASER RADIATION ON A PHOTOSENSITIVELY COATED SUBSTRATE

(57) Abstract

This invention relates to a method for writing on a photosensitive surface a pattern described in input data by scanning at least one modulated laser beam in parallel scan lines while moving along scan stripes in a direction perpendicular to the scan lines. The method comprising the steps of dividing said input data into partially overlapping stripe pattern data corresponding to scan stripes having stripe overlap regions, providing a predetermined exposure blend function along the scan line, said blend function starting and ending with a 0 % value and further having a 100 % value near the center of the scan line, and modulating the laser beam with the product of the exposure blend function and the stripe pattern data. The invention also includes an apparatus for writting patterns according to the above mentioned method.

METHOD AND APPARATUS FOR
THE PRODUCTION OF A STRUCTURE BY FOCUSED LASER
RADIATION
ON A PHOTOSENSITIVELY COATED SUBSTRATE

BACKGROUND OF THE INVENTION
1.   Field of the Invention

The invention relates to a surface pattern produced
on photosensitively coated substrate by a focused laser
beam, and method and an apparatus for producing such a
pattern. In particular, the invention is directed to
methods and apparatus for producing structures of chro-
mium on glass which are suitable for use as masks or
reticles for photolithography in semiconductor produc-
tion.

2.   Earlier problems

Masks and what are known as reticles with extremely
accurate structures of chromium on glass substrates are
used for the production of photolithographic structures
or patterns in the production of semiconductors. A 5X
reticle, that is to say a pattern or structure which is
photographically reduced five fold on to the semiconductor
wafer and which constitutes the most widespread type of
mask in the near future may comprise a quartz plate meas-
uring 150 mm x 150 mm which has a structure of opaque
chromium. The structure is formed by exposure to light or
an electron beam of a photosensitive or electron-sensi-
tive covering on the chromium film. The photosensitive or
electron-sensitive covering is then chemically developed
and the exposed part thereof is removed. In a subsequent
etching operation, the chromium is etched away at the
locations at which the covering has been removed and the
chromium film which remains forms the pattern or struc-
ture.

The smallest line widths of known 5-fold reticles
are about 2 microns. However the required level of accu-
racy is considerably higher. Admissible overlay errors,
that is to say the admissible difference between the
position of the edges of the chromium in identical reti-
cles produced in two successive steps is to be of the
order of magnitude of 0.05 micron.

Reticles are mainly used for the production of accu-
rate structures or patterns in the semiconductor indus-
try. However there are also many other applications, for
example in the field of integrated optics, diffraction
optics, computer-generated holograms, micro-machining of
miniaturized sensors, optical information storage and
superconducting devices. Other important applications are
direct exposure of patterns on semiconductor wafers and
pattern generation for large-area displays. The high
costs of existing production equipment for surface pat-
terns or structures with a sufficient degree of accuracy
and in particular using electron beam reticle writers
represent an obstacle to the development of new equipment
in these little established areas, in particular in uni-
versities and smaller companies.

A common aspect of all known pattern generators is
that the mask or reticle is described in a digital data
bank containing a list of all structure or pattern ele-
ments with their geometrical data. Before the structures
are written, the geometrical data are converted to the
format which is used by the writing hardware. During that
conversion operation the geometrical co-ordinates are
truncated to the addressing resolution of the hardware,
that is to say the writing address grid.

Most modern pattern generators use a raster scan
principle with a scanning beam which is either an elec-
tron beam or a laser beam and which is deflected along
parallel lines on the substrate which is covered with a
radiation-sensitive covering. The beam is switched on and
off in dependence on a bitmap for the structure, which is

stored in the control system. Another option is that the beam is produced during a writing time which is derived from data stored in an intermediate compressed format.

5   For a pattern or surface structure with an address grid or raster of 0.5 micron, it is possible to produce a bitmap with a bit for each grid point, a digital bit for each pixel, i.e., each individually controllable area element.

In principle a pattern with an addressability of
10   0.05 micron could also be written with scan lines at a spacing of 0.05 micron and with a pixel spacing of 0.05 micron along the scan line. However a bitmap with a 0.05 micron grid and a surface cover rate as referred to above corresponds to a data rate of 2-4 Gbits per second. It is
15   not possible to modulate a single writing beam at that rate. In addition the data volume is one hundred times greater than for the 0.5 micron grid and is fairly unman-ageable. Even real-time expansion from the compressed data format is impracticable as the flow of data would
20   choke the data buses of most processors. Technological limitations in regard to modulation rate and data flow would severely limit the writing speed and make it impos-sible to use a reticle writer with a full pixel map with a 0.05 micron address grid.
25

3.   Solution to earlier problems and description of prior art
An method and an apparatus to solve the above men-tioned problems was presented by the inventor of the pre-
30   sent invention in DE-P 40 22 732.4. This method and this apparatus will be described in detail below. The apparatus includes data delivery means for controlling the input of said modulator while the laser beam is scanning. Gener-ally, the data delivery means includes a clock having a
35   predetermined clock period between clock pulses, so as to establish a regular train of clock pulses. A data proc-essing unit is also provided for accepting input data and

computing or establishing beam intensity data and beam
position data for an edge in the pattern. Both the beam
intensity data and the beam position data are established
in a digital format. The apparatus also includes as part
5   of the data delivery means a signal processing unit for
converting the beam position data to an equivalent time
for positioning the laser beam along the scan line during
scanning. Particularly, this equivalent time is converted
as an integer number of clock pulses plus a fractional
10 remainder. To create a time pulse corresponding to the
equivalent time, digital counting means may be provided
for generating a timing pulse at a time corresponding to
the integer number of clock pulses and a time delay cir-
cuit may be provided for incurring to the timing pulse a
15 time delay equal to the fractional remainder. Once the
corresponding time pulse is created, a circuit may be
used for setting the modulator input signal to the digi-
tal beam intensity data at the arrival of the timing
pulse.

20   With reference now to the preferred embodiment shown
in Fig. 1, the repeated loading of Run Length Encoded
(RLE) data items into a modulator driver logic means 6
occurs at a rate which is normally lower than the pixel
rate. Data loading occurs at the rate of a data delivery
25 clock which has a clock speed which is compatible with
standard IC families, for example FAST-TTL. Two data
items can be combined to provide a data word for effec-
tive use of the available bits. The modulator driver
logic means 6 separates the power and change position
30 fields at the input and supplies a modulation means 5
with the power control signal after a time which is
derived from one or both of the last position fields. If
the data delivery clock is of a frequency which is lower
than the pixel rate, which is normally the case, the
35 delay in the modulator control signal is not generated by
a counter but preferably by selection from the various
clock signals with time delays between them.

The beam power may be modulated either by modulation
of the light source or by using a modulator with a con-
tinuous light source. It is also possible to provide for
a non-linear relationship between the exposure of the
outermost pixel at the edge of an element of the struc-
ture and displacement of that edge, by using a table
lookup or reading procedure or other correction proc-
esses. It is also possible to modify the exposure of more
than one row of pixels along the edge in order to produce
an exposure gradient which is independent of the position
in relation to the scan lines.

It is possible for the apparatus and method to be
used in such a way that successive pixels, with unchanged
power, can be written without more than one control word
being generated.

Reference will now be made to Fig. 1 showing a pre-
ferred embodiment of an apparatus for producing surface
patterns or structures on photosensitively coated sup-
ports or substrates. In the illustrated embodiment, the
substrate as indicated at 3 is in the form of a glass
plate which is covered with a photosensitive coating, for
example a photoresist. The glass plate 3 is disposed on
an object table 19 which is movable in the X- and Y-di-
rections. A writing head with a focusing lens 15 and a
deflector device 14 which is preferably in the form of an
acousto-optical deflector device is arranged to be sta-
tionary in the X- and Y-directions. However the focusing
lens 15 is freely movable in the vertical direction (the
Z-direction). It is disposed a few microns above the sur-
face of the glass plate 3 on an air cushion. As the air
cushion is loaded only with the weight of the focusing
lens 15, the height of the air cushion can be kept con-
stant, by virtue of the independence of the Z-co-ordi-
nate, so that the surface of the glass plate always re-
mains in the focal plane, even if the surface is uneven.

A laser beam source 13 produces a laser beam which
is modulated in regard to its power and in particular its

intensity by a modulator device 5, more especially an acousto-optical modulator device. The focusing lens 15 focuses on the laser beam and forms a focused laser beam as indicated at 1, which is directed on to the surface of

5   the glass plate substrate 3.

For monitoring the positioning of the object table 19, the apparatus has position monitoring devices 18x and 18y which monitor the positioning of the object table 19 in the X- and Y-directions relative to the writing head

10   (deflector device 14 and focusing lens 15). Together with electric motors 17x and 17y, the position monitoring devices 18x and 18y form a servo mechanism which produces the precisely controlled movement of the object table 19.

The servo mechanism which is operative in the X-

15   direction moves the object table 19 by means of the electric motor 17x which is preferably in the form of a linear motor, in the X-direction at a constant speed for producing stripes 30 of a given width when the laser beam 4 scans along the scan lines 2. When a respective stripe

20   30 is completed, the X-servo mechanism performs a retrace stroke movement into the starting position and the object table 19 is then moved in the Y-direction by the width of a stripe by the electric motor 17y which is also preferably in the form of a stepping motor.

25   A scanning circuit 26 generates a high frequency deflection signal with linear ramp function. The scanning circuit 26 is connected to the deflector device 14. That arrangement produces linear deflection of the laser beam 1 in the width of the respective stripe 30. The focal

30   spot of the focused laser beam 1 is deflected on the surface of the glass plate 3 along the scan lines 2 which extend normal to the longitudinal extent of the stripes 30. Reference numeral 8 in Fig. 1 identifies the positions of the pixels in the scan lines 2 in a purely dia-

35   grammatic fashion, that is to say, not to scale.

The laser beam source 13 which is for example an HeCd laser generates the laser beam 1 at a preferred

wavelength of 442 nm. The laser beam is passed through
the acousto-optical modulator 5 which is actuated by a
high-frequency modulation drive signal 4. The modulation
drive signal 4 is supplied by the modulator driver logic
5   means 6. The intensity or power of the modulation drive
signal 4 is controlled by an analog modulation drive sig-
nal of a digital-analog converter. The digital-analog
converter which is disposed in the modulator driver stage
or logic means 6, as shown in Fig. 3, is controlled by a
10   power control signal 7 by way of a storage device which
is preferably in the form of a register, for storage of
the digital power control word required for producing the
control effect.

Reference will be made at this point to Fig. 3 show-
15   ing a preferred embodiment of the modulator drive logic
means 6 described above with reference to Fig. 1. It has
two storage devices for bit words, in the form of regis-
ters 605 and 608. The register 605 is loaded with inten-
sity or power data 7 coming from the data delivery device
20   24 shown in Fig. 1. The register 608 is loaded with posi-
tion or delay data 25 which also come from the data
delivery device 24. That takes place on the basis of a
transition caused by the clock signal 31. In that
arrangement, a digital-analog converter 606 is also oper-
25   ated by power data previously stored in the storage
device 607. It may also be in the form of a register. A
digitally controlled delay circuit 609 transfers the
clock signal 31 to its output side, with a delay which
depends on the data stored in the register 608. After
30   that delay the active edge of the clock signal is sup-
plied at the output 610 of the delay circuit 609. The
value stored in the register 605 is loaded into the reg-
ister 607 and passed to the input side of the digital-
analog converter 606. After an internal delay in the
35   digital-analog converter 606, a fresh analog power con-
trol signal 7 occurs at the output of the modulator
driver stage of the modulator device 5.

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Going back now to Fig. 1 in which it will be noted that the thick arrowed lines represent the flow of data relating to the structure and the thin lines represent the lines for the control signals, the Fig. 1 embodiment
5   further includes the writing control unit 29 which can be in the form of a processor. The control unit 29 initiates the operation of reading the data from a storage device 23 and sends instruction or command signals to an XY-servo control unit 27 for controlling the movement of the
10   object table 19. A clock generator 28 generates the clock signal 31 which synchronizes operation of the data delivery logic means or device 24, the modulator driver logic means 6 and the deflector circuit 26. The servo control device 27 further supplies a separate readiness signal 32
15   to the deflector circuit 26. That readiness signal 32 ensures that operation of the deflector device 14 does not occur until the object table 19 reaches its correct X-position. That provides for accurate positioning of the object table 19, in regard to the deflector device 14. As
20   the modulator device 5 and the deflector device 14 operate in an inertia-free fashion and are driven by the same clock signal 31, that arrangement provides a high degree of positional accuracy.

The XY-servo control unit 27 thus co-operates in
25   timed relationship with the servo system 17x, 17y, 18x, 18y and the deflector circuit 26, so as to ensure that the scan line stripes 30, scanning in the respective stripe width by the deflector device 14 and modulation by the modulator device 5 are performed synchronously.

30   The apparatus may also use a plurality of writing beams instead of the single writing beam. Such a procedure then requires a suitable number of modulators, lenses, parallel data paths and so forth.

The position field contains sufficient data to com-
35   pute an absolute position for a change in power, but the position field is not necessarily encoded as an absolute position. Particularly when using paired power and run

length data, run length encoding can be effected either as a spacing in order to retain the current value before the next change, or as a spacing in order to retain the next current value, or as an absolute position at which the next value begins, or as an absolute position at which the next value ends, or as any other adequate encoding. In addition the position field may contain two sub-fields with one sub-field being absolute and another being relative. Instead of the modulator device 5, it is also possible to use a modulated light source, for example a semiconductor laser or a plurality of semi-conductor lasers. Still continuing now with the description of the apparatus shown in Fig. 1, a data input device 20 includes input data for the structure as indicated at 9, which is to be produced on the substrate 3. Such data occur in the form of a list of structure or pattern elements 12 and 16 or regular structure formulae or constants so that the structure elements can be computed. The specification of exposure can be standardized to a maximum exposure or implicitly assumed in the case of a single exposure value for all patterns. In all cases X- and Y-length scales, the angle between the axes and the absolute exposure dosage can be modified by the operator, from what is specified in the input data. It is also possible to carry out other data processing operations, for example mirroring, inversion, gray-scale corrections and pre-compensation operations for underetching or proximity effects. The delivery clock may be a single-phase or multi-phase clock and loading of the run length encoding data items may be effected in one register or in two or more registers. The decoding logic may involve a pre-recall operation or other buffers in order to increase operating speed.

For the purpose of increasing operating speed it is also possible to multiply a part of the data paths, for example to provide a plurality of modulator driver logic means, even if only one laser beam is used.

The relative movement as between the writing head
and the substrate can be produced by the writing head
moving relative to the stationary substrate or vice-
versa. It is also possible for the writing head to be
5   moved in one direction and for the substrate to be moved
in a direction perpendicular thereto.

For purpose of further explanation, reference is
made to Fig. 2a, which shows a fixed grid with small cir-
cles showing the diffraction-limited extent of each
10   pixel. The pixels are centered on a pixel grid 504 and a
scan line stripe 503 is formed by successive scan lines
indicated at 502. The pixels are centered on the scan
line 502 and are arranged at equal spacings from each
other. The pixel spacing and the spacing of successive
15   scan lines 506 are the same. Fig. 2a shows an exposed
scan line 502 and a region which is filled with pixels
and which extends over three stripes 503. That region has
an edge 505 which extends inclinedly relative to the ver-
tical and an edge 506 which extends inclinedly relative
20   to the horizontal. With the illustrated structure it is
not possible for the edge to be positioned at fractional
pixel points so that the inclined edge configuration is
of a jagged or ragged configuration.

In contrast, Fig. 2b shows a pixel arrangement in
25   which the pixel density along the scan lines 502 is
higher, more specifically by a factor of at least four,
than in the direction of the longitudinal extent of the
stripes 503 or normal to the scan line 502. That is also
indicated in Fig. 2b by the spacings A1 and A2. A1 iden-
30   tifies the spacing of the respective pixel addressing in
a scan line 502 while A2 identifies the spacing of the
respective scan lines 502 from each other. As can be seen
from Fig. 2b, that provides for extremely fine addressing
at the vertical edge. It is therefore possible to have a
35   relatively smooth configuration, even in the case of an
edge as indicated at 508 which extends inclinedly rela-
tive to the vertical.

The power modulation effect also improves an edge
509 which extends inclinedly relatively to the horizon-
tal, as can be clearly seen from Fig. 2b.

In operation, and with reference to Fig. 1, the geo-
metrical properties of the structure 9 to be produced or
the structure elements 12, 16, together with their expo-
sure, are specified in the data input means 20 in a for-
mat which is transmitted to a data processing device 21.
The data processing device 21 provides for conversion of
the geometrical data into an intermediate compressed for-
mat 22. The compressed format 22 is inputted into a digi-
tal storage device 23. The compressed format is also
passed to a data delivery device 24 in which the stored
data are processed to provide an internal data format
comprising a pair of data contents 7 and 25, namely a
data content 7 in relation to beam power and a data con-
tent 25 in relation to position. The data content 25 may
include delay data, as has already been described above
with referenced to Fig. 3. The data content 7 in relation
to beam power is passed in the form of a power control
signal 7 to the modulator driver stage 6 while the data
content 25 in relation to position is passed in the form
of a position signal 25 to the modulator driver stage 6.
The modulator driver stage 6 which is in the form of a
logic circuit calls up those data from the data delivery
device 24. The modulator driver stage 6 supplies the
modulation drive signal 4 which is variable at the pixel
points 8 arranged at regular spacings along the scan
lines 2 extending normal to the stripes 30.

4.   Problems with prior art

One important performance criterion in a scanning
pattern generator is the ability to print small pattern
elements across the boundary between adjacent scan
stripes without error. Typically, each stripe is slightly
displaced relative the adjacent ones, since they are not
written at exactly the same time and any system has some

drift and position noise. A mismatch between the patterns
on two sides of a stripe boundary is referred to here as
butting error. Therefore, if a small pattern element is
located across a stripe boundary, a size error of the
5   pattern element will typically occur due to the butting
error.

    An example of such a size error is provided for pur-
pose of explanation and not limitation. In a 5X photomask
for a 0.5 μm VLSI device, the transistor gates are 2.5 μm
10   long. The need for absolute position accuracy in the mask
may be 100 nm (three sigma value). But if the stripes are
randomly displaced by ±100 nm, somewhere in the mask
there can be a relative displacement between two adjacent
stripes of perhaps 170 nm. If transistor gates are placed
15   across this stripe boundary, they are dilated by 170 nm,
or 7% of 2.5 μm. This size error affects the characteris-
tics of the transistors and can cause malfunction of the
entire circuit, or lower the tolerance to other process
errors, thus lowering the process yield.
20   One known method to reduce butting errors is to
write several passes with the stripes displaced between
the passes. Butting errors are averaged out, but the
method is wasteful because essentially the same pattern
has to be written several times.
25

SUMMARY OF THE INVENTION

    With the parallel scan lines forming scan stripes
along the substrate, such that the scan lines extend
transversely across the respective scan stripe, the
30   invention includes methods and apparatus to suppress the
visibility of the end boundaries of the stripes, particu-
larly those end boundaries between adjacent stripes that
may otherwise be caused by the apparatus that is used for
writing a structure on a photosensitive surface of a sub-
35   strate. In accordance with the invention, the stripes are
made to overlap each other.

According to one aspect of the invention the transition from one stripe to the next is synchronized to the position of feature edges in the data.

According to another aspect of the invention the
5   stripes are blended in the overlap according to a prede-termined stepwise changing function. By this method the benefits of the invention can be maintained across the stripe boundaries, which are rendered virtually invisible for all valid input data. This is done with a very small
10   expenditure of increased complexity, data volume, and data preprocessing.

It is to be understood that both the foregoing gen-eral description and the following detailed description are exemplary and provided for purposes of explanation
15   only, and are not restrictive of the invention, as claimed. Further objects, features and advantages of the present invention will be apparent from the following description.

20   BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate the preferred embodiment of the invention, and together with the description, serve to explain the principles of
25   the invention.

Fig. 1 shows an apparatus for producing a surface pattern or structure according to a prior-art method.

Fig. 2a is a fixed pixel grid.

Fig. 2b shows a pixel arrangement according to
30   prior-art.

Fig. 3 shows an embodiment of a modulator driver logic that can be used in the apparatus of Fig. 1.

Fig. 4 is an illustrative representation of a pat-tern having an area extending slightly across the stripe
35   boundary that is smaller than the minimum feature size desired.

Fig. 5 is an illustrative representation of an
aspect of the invention, wherein the stripe boundary
between adjacent stripes is moved for each scan line to
eliminate pattern areas that would otherwise be smaller
5   than the desired minimum size.

Fig. 6 is an illustrative representation of another
aspect of the invention, wherein the pattern is divided
into partially overlapping stripes and the exposure is
blended in the overlap by an exposure blend function.
10   Fig. 7 shows an embodiment of a modulator driver
logic of the invention that may be used for blending of
overlapping stripes of Fig. 6.

Fig. 8 is a position and time chart, which illus-
trates the function of the embodiment of Fig. 7.
15

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Writing of arbitrary patterns may be performed
accurately and efficiently using the above described
method and apparatus. Preferably, however, it is desir-
20   able that the following two conditions are met. First,
the modulator drive signal should only change value once
per data clock period. Second, the time between two suc-
cessive changes in the modulator drive signal should not
be smaller than a specific value, referred to hereinafter
25   as the minimum feature size. In accordance with the first
condition, features longer than one clock period can
always be written regardless their position relative to
the grid. The minimum feature size of the second condi-
tion, therefore, is generally considered to be one clock
30   period.

In practice, it is possible that a portion of a pat-
tern will be smaller than the minimum feature size when
the pattern is cut or divided into scan stripes. For
example, and with reference to Fig. 4 for purpose of
35   explanation, two sets of parallel scan lines 701, 702
form two adjacent scan stripes and share a stripe
boundary 703. Positions along the scan line corresponding

to the clock pulses are shown as lines 704, and the mini-
mum feature size is equal to one clock cycle 705.
Although a long feature 706 can be divided without prob-
lems at the stripe boundary 703, features that protrude

5   only slightly into an adjacent stripe will produce small
pattern elements 707 that may violate the minimum feature
size condition when divided.

One method used by the assignee of this application
to avoid violation of the second condition is to generate

10   features that satisfy the minimum feature requirement and
extend outside the scan stripe. An independent gating or
window signal is then used to cut the features at the
stripe boundary. In this manner, very short pulses can be
generated when necessary. However, the low-pass charac-

15   teristics and non-linearity of the modulator distorts the
short pulses, and a pattern like that in Fig. 4 is still
difficult to write without visible artifacts.

In accordance with an additional aspect of the
invention, therefore, the method and apparatus embodied

20   herein prevents any pattern elements smaller than the
minimum feature size from being written. Particularly,
the method and apparatus of the invention changes the
position of the stripe boundary from scan line to scan
line depending on the written pattern. Fig. 5 shows the

25   placement of the boundary for a number of cases, wherein
the transition between exposed and unexposed elements
801, 802 is performed using different power levels rather
than a modulator on-off process. In each case, the bound-
ary is placed so that the exposed and unexposed elements

30   are at least as large as the minimum feature size, so as
not to violate the second condition defined above. Fig. 5
further shows that there also may be an overlap 803 of
the scan lines 804 and 805 of at least twice the minimum
feature size 806. Within this overlap 803, there is

35   either a transition in the modulator drive signal, or the
pattern feature is long enough to be cut in two parts
satisfying the minimum feature size condition.

In accordance with an important aspect of the invention, a method and apparatus is provided to reduce the influence of butting errors with a minimal loss of through-put. In the invention, a moderate overlap between

5   successive scan stripes is introduced and the stripes are blended in the overlap region. The transition from one stripe to the next is not abrupt, and the butting errors are effectively distributed over the overlap region, typically between about 5 to 10% of the stripe width.

10   Therefore, and with reference to the drawings of the example set forth above, the butting error can be spread out over an overlap of 10 μm. In this manner, a feature that is 2.5 μm will see only one fourth of the total butting error, i.e., 42 nm or less than 2% size error.

15   Fig. 6 is a schematic representation of the overlap and blend function of the invention. The pattern data 901 is cut or divided into data stripes 902 and 903, wherein the data stripes 902 and 903 partially overlap each other. An exposure blend function 904 determines the

20   exposure energy along a scan line. The blend function 904 is established so that the data stripes, when blended together, produce an even exposure of the pattern. Specifically, the blend function is used to modulate the exposure level of the pattern data of each data stripe,

25   so that the exposure is the product of the pattern data and the blend function.

To perform the blend function and thus reduce the influence of butting errors, it is possible to let the light beam pass two modulators in series, one for the

30   data and one for the blend function. More convenient, however, is to combine the data and blend function into a single electronic signal that is fed to a single modulator. In this manner, the use of one modulator rather than two allows for better light efficiency, since each modu-

35   lator has an insertion loss of approximately 20%. Additionally, an optical train having a single modulator is also considerably less complicated, less expensive, and

easier to adjust than one having two modulators in
series.

The preferred embodiment of the apparatus used for
performing this combined modulation is shown in Fig. 7.
5   This modulator drive logic 6 includes all the same ele-
ments as that of Fig. 3, as indicated by the same refer-
ence characters, as well as additional elements to per-
form the exposure blend function.

As noted above, modulator drive signal 4 is produced
10 using both time delay data 25 and power data 7. The expo-
sure blend function is stored in the lookup memory 1001,
which can be loaded through the processor interface 1002.
The intensity data 7 and the clock count 1003 within the
scan line are used to address one cell at a time in the
15 lookup memory 1001. In turn, the lookup memory 1001 out-
puts for each clock cycle an intensity value 1004 that
corresponds to the product of the power blend function
and power data and is corrected for the non-linearity of
the modulator. Additionally, the time delay circuitry-
20 608, 609, 607 works substantially identically to that of
Fig. 3 except the latch 607 is clocked not only when the
power input data 7 changes, but at every clock cycle in
order to update the digital-analog converter with new
values of the exposure blend function.

25   The cycle count comes from the counter 1006, which
counts cycles on the data clock 31 and is reset at the
start of every scan line by a start-of-scan pulse 1007. A
congestion detector 1005 is added to assure that the
minimum feature size condition is not violated, and
30 removes one clock pulse if it is. The removed clock pulse
is one that does not refer to a transition in the power
data 7. This process causes a variation in the function
that is difficult to predict before-hand, but is com-
pletely determined by the input data. The patterns in the
35 stripes are identical in the overlap and the circuit
works exactly the same in both stripes. The principle is
to let the timing of the exposure blending synchronize to

the pattern data in a deterministic way so as to have
exactly the same pattern in both stripes.

Fig. 8 is a position and time chart, which depicts
how two stripes are blended in the overlap region. The
5   pattern to be written 1101 consists of elements with two
different exposure levels 1102, 1103. The graph 1104 is
the exposure E to be written corresponding to the pattern
1101. The horizontal axis therefore represents both a
position axis and a time axis, since the scanning is lin-
10   ear from left to right. The two stripes are shown by the
arrows 1105 and 1106, respectively, with the overlap
identified by reference character 1107. The vertical
lines 1108 in the position and time chart represent the
clock pulses.

15   The right and left ends of the exposure blend func-
tion are shown by the graphs 1109 and 1110. Likewise, the
value of the modulator drive signal for each of the two
stripes is shown by the graphs 1111 and 1112, respec-
tively. It is shown that graph 1111 is the product of
20   1104 and 1109, while graph 1112 is the product of 1104
and 1110. Additionally, and for purpose of example, it is
shown that the steps in 1109 are synchronized within one
clock cycle with the steps in the data, except for the
step 1113 where the congestion detector has delayed it
25   one more cycle, since it would violate the minimum fea-
ture condition described above if it was allowed to occur
in its own clock cycle.

When combined, the sum of 1111 and 1112 is equal to
1104. The pattern 1101 corresponding to the data 1104 is
30   therefore blended in the overlap between the stripes 1105
and 1106 by the blend functions 1109, 1110, and the blend
function timing is synchronized to the data to produce
the modulator drive signals 1111 and 1112. Additionally,
the stripes preferably extend two clock cycles outside
35   the region where the blend functions are both non-zero.
This is to make sure that the patterns in both stripes
are identical and that no end effects alter the synchro-

nization of blend functions to data where there is expo-
sure in both stripes.

The shape of the exposure blend function, the length
of the overlap, and the number of steps from 0 to 100%
are determined by the system software, and can be made
parameters to be input by the user of the pattern genera-
tor. For a very critical pattern, the overlap can be
increased up to half the stripe width and the number of
steps can be increased, while for a less critical job the
overlap can be reduced for higher through-put. The con-
tents of the lookup memory are calibrated by measurement
of the actual beam power to make the true exposure follow
the theoretical blend function.

In a further embodiment of the invention, the expo-
sure blend signal also contains information regarding
exposure variations along the scan line, in addition to
the information of the blending in the overlap region. By
measuring the true exposure along the scan line and add-
ing an appropriate correction to the exposure blend func-
tion, any unwanted exposure variations can be removed.
The corrections are of a very small magnitude, typically
about 2%, and the unpredictability of timing caused by
the congestion detector is generally unimportant.

The above described methods with syncronization and
blend function can be used separately or combined with
each other. The synchronization can hereby depend on
boundaries on an exposed surface, or boundaries detected
in the input data controlling the beam before the
exposure.

It will be appreciated that the above-described
description of the present invention has been set forth
solely by way of example and illustration of the princi-
ples of the present invention and that various other
modifications and alterations may be made therein without
thereby departing from the spirit and scope of the inven-
tion.

CLAIMS

1.   A method for writing on a photosensitive sur-
face a pattern described in input data by scanning at
least one modulated laser beam in parallel scan lines
while moving along scan stripes in a direction perpen-
dicular to the scan lines, the method comprising the
steps of

dividing said input data into partially overlapping
stripe pattern data corresponding to scan stripes having
stripe overlap regions,

providing a predetermined exposure blend function
along the scan line, said blend function starting and
ending with a 0% value and further having a 100% value
near the center of the scan line, and

modulating the laser beam with the product of the
exposure blend function and the stripe pattern data.

2. A method as set forth in claim 1, wherein the
exposure blend function has intermediate values in the
overlap regions, and preferably two or more such
intermediate values.

3.   A method as set forth in claim 2, wherein the
shape of the exposure blend function is software-con-
trolled and can be changed by the operator.

4.   A method as set forth in claim 1, wherein the
stripe overlap has a width that is software-controlled
and can be changed by the operator.

5.   A method as set forth in claim 1, wherein for
each laser beam the exposure blend function and the
stripe pattern data are combined into a single modulation
signal and fed to a single modulator.

6.   A method as set forth in claim 5, wherein the
data fed to the modulator is applied with pattern-depend-
ent time delays, and further wherein transitions between
different values in the exposure blend signal occurring
close in time to transitions in the stripe pattern data

are synchronized to the timing of the stripe pattern
data.

  7. A method as set forth in claim 6, wherein the
stripe pattern data is at least one clock cycle wider
than the region where the exposure blend function is non-
zero.

  8. A method as set forth in claim 6, wherein a
congestion detector monitors the time delay data to indi-
cate when two transitions in the modulator signal occur
less than one clock cycle apart, and to change the timing
of one of the transitions.

  9. A method as set forth in claim 5, wherein the
combination is done by table lookup, and the table lookup
is calibrated by measurement of laser beam power.

  10. A method as set forth in one of the claims 2-9
wherein the boundary between intermediate values in the
blend function in the stripe overlap regions, is
synchronized according to input data for the pattern in
the overlap regions.

  11. A method as set forth in claim 10, wherein the
synchronization is controlled according to boundaries in
the input data before exposure.

  12. A method as set forth in claim 10, wherein the
synchronization is controlled according to edges in the
exposed area to a transition by a modulator drive signal
as specified in the input data for the beam.

  13. A method as set forth in claim 1, wherein the
stripe boundary in a scan line where the writing ends in
one stripe and starts in the corresponding scan line in a
adjacent stripe, is synchronized to a transition by a
modulator drive signal as specified in the input data for
the beam.

  14. A method as set forth in claim 13, wherein the
beam data in the overlapping regions of two stripes are
identical and line-by-line synchronization between the
stripe boundary and the transitions in the beam data is
done by a synchronization circuit at the time of writing.

15. An apparatus for writing patterns described in input data by scanning at least one modulated laser beam in parallel scan lines while moving along scan stripes in a direction perpendicular to the scan lines, the apparatus comprising:

a data preprocessing system for converting the input data to pattern modulation data corresponding to the patterns in partially overlapping stripes, wherein the scan stripes have stripe overlap regions,

a digitally stored exposure blend function having a 0% value at the ends of the scan line, a 100% value near the center of the scan line, and

modulation means for modulating the laser beam with the product of the pattern modulation data and the exposure blend function.

16. An apparatus as set forth in claim 15, where the blend function comprises intermediate values for positions corresponding to the stripe overlap regions.

17. An apparatus as set forth in claim 15, further including

time delay circuitry to delay transitions in the modulation data for higher address resolution than corresponding to the data clock pulses, and

synchronization circuitry to synchronize transitions in the exposure blend function to delayed transitions in the pattern modulation data.
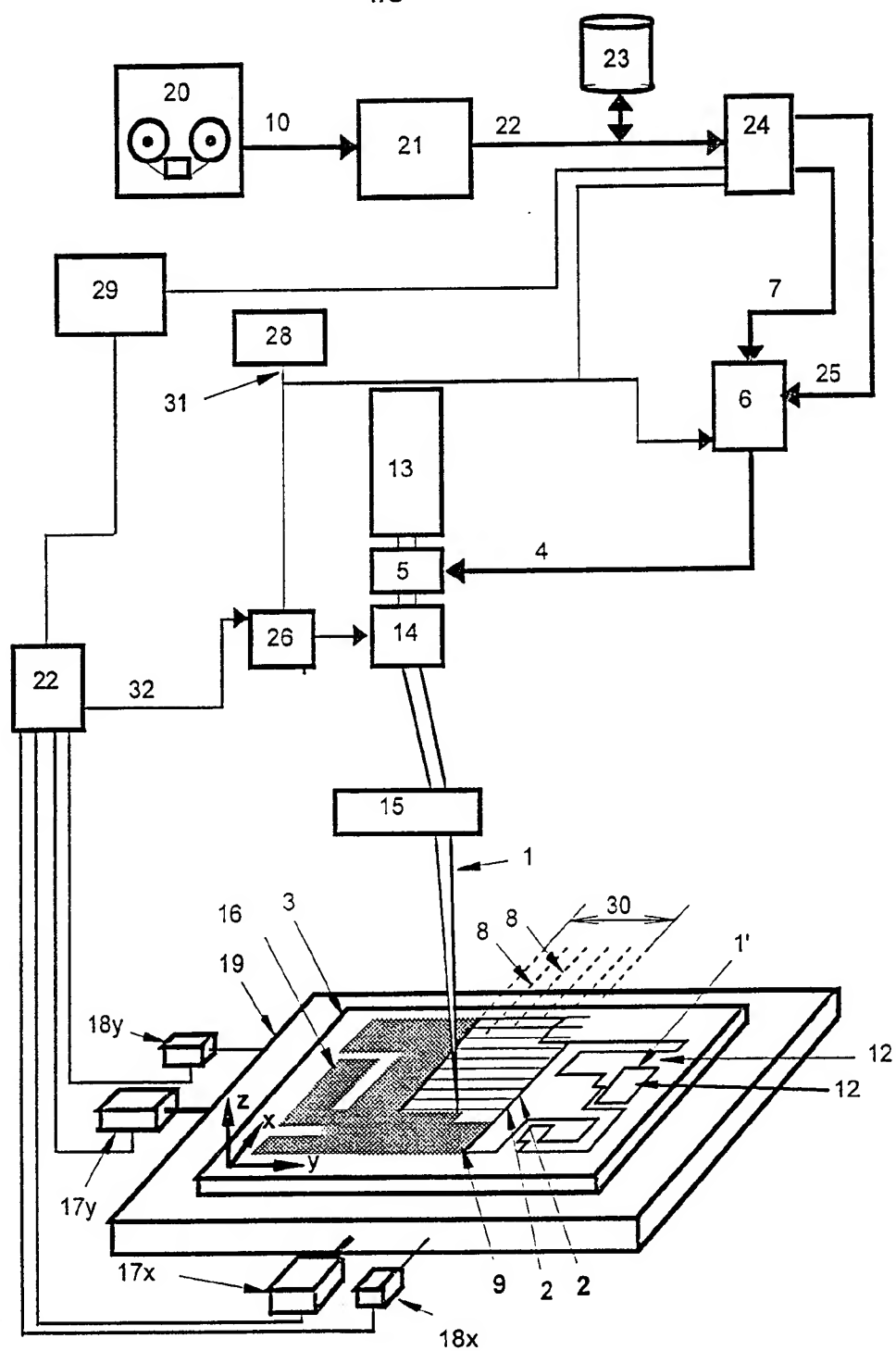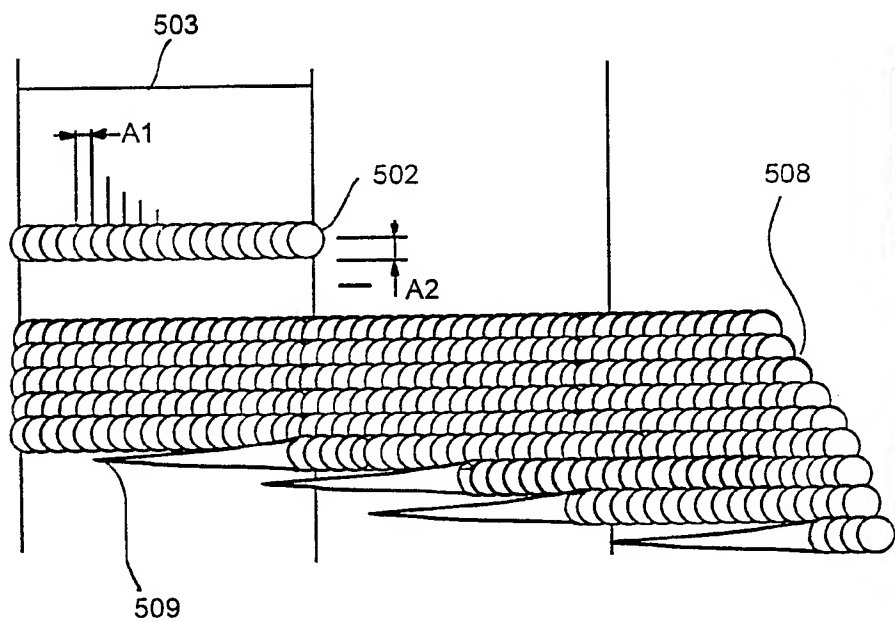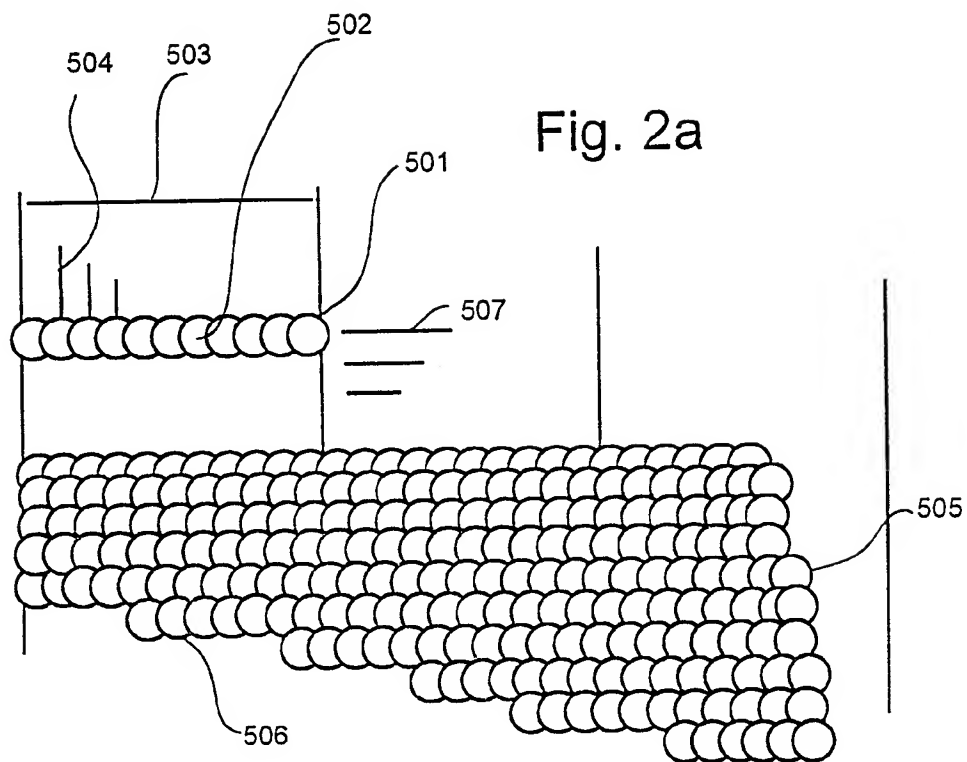
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Fig. 1

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Fig. 2a

Fig. 2b

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25   7

31 ── 6

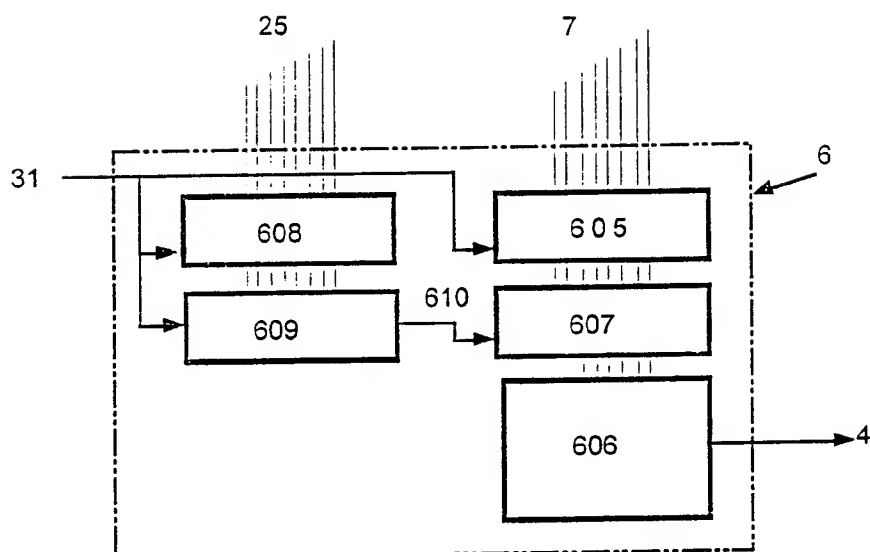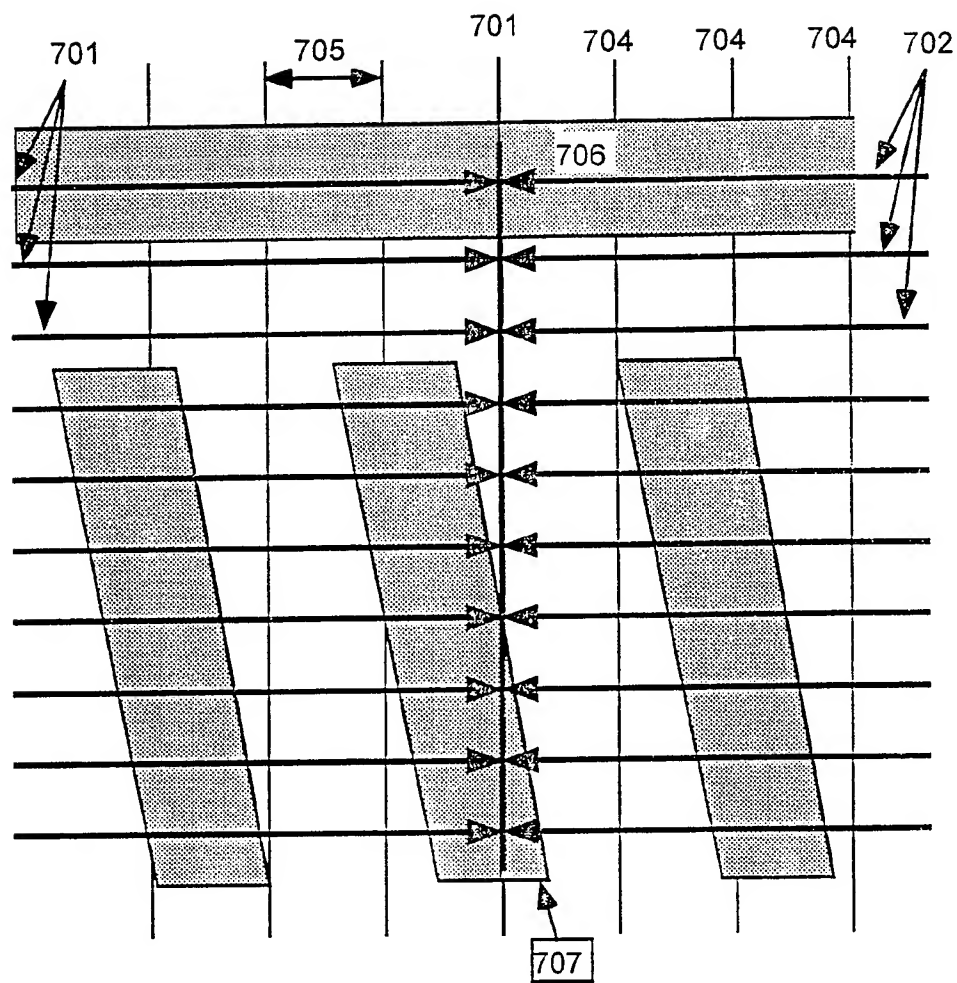608   ────▶   6 0 5

610
609   ────▶   607
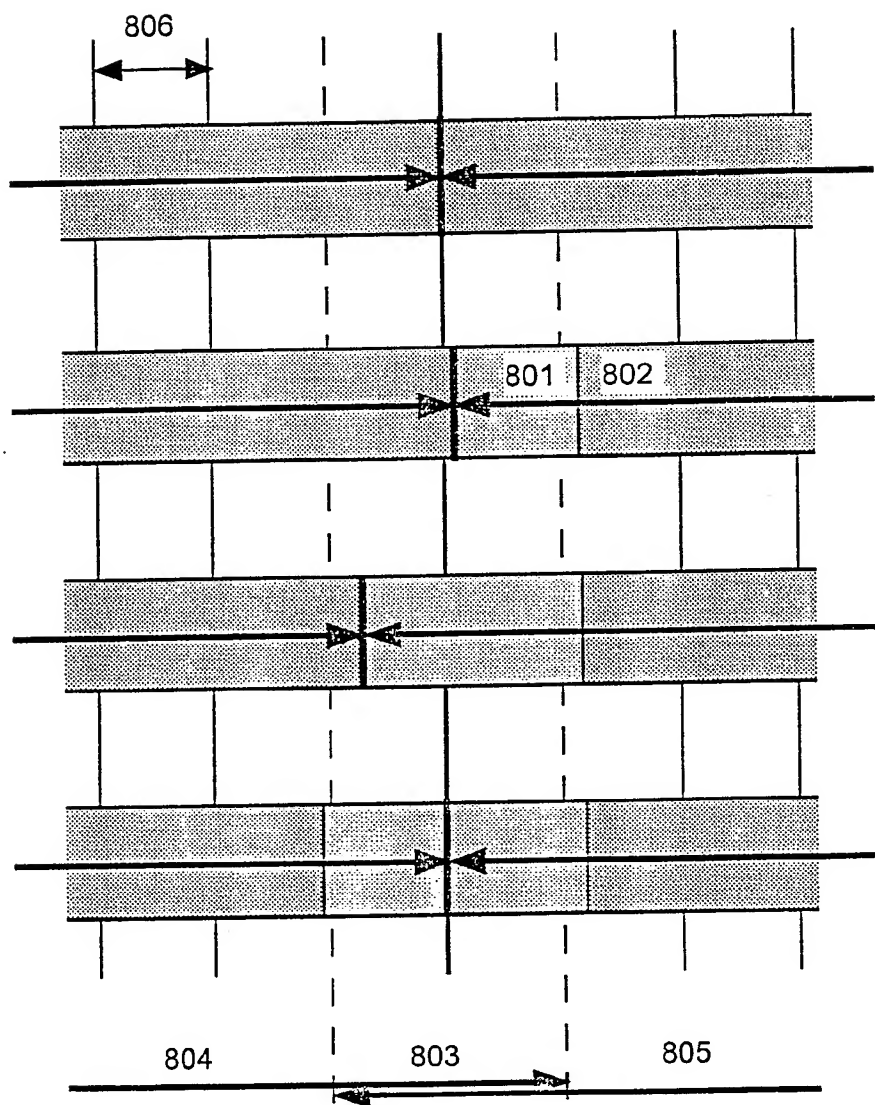
606   ──────▶ 4

Fig. 3
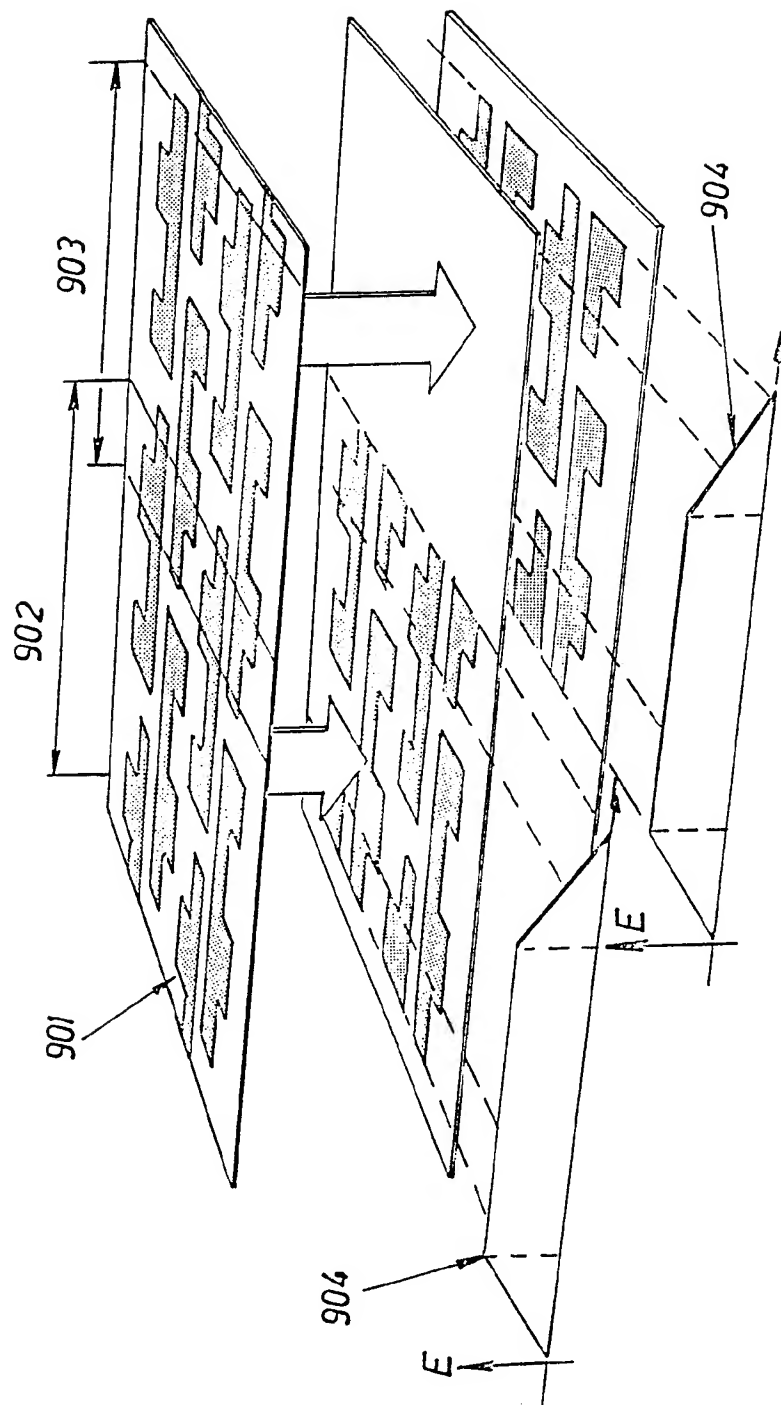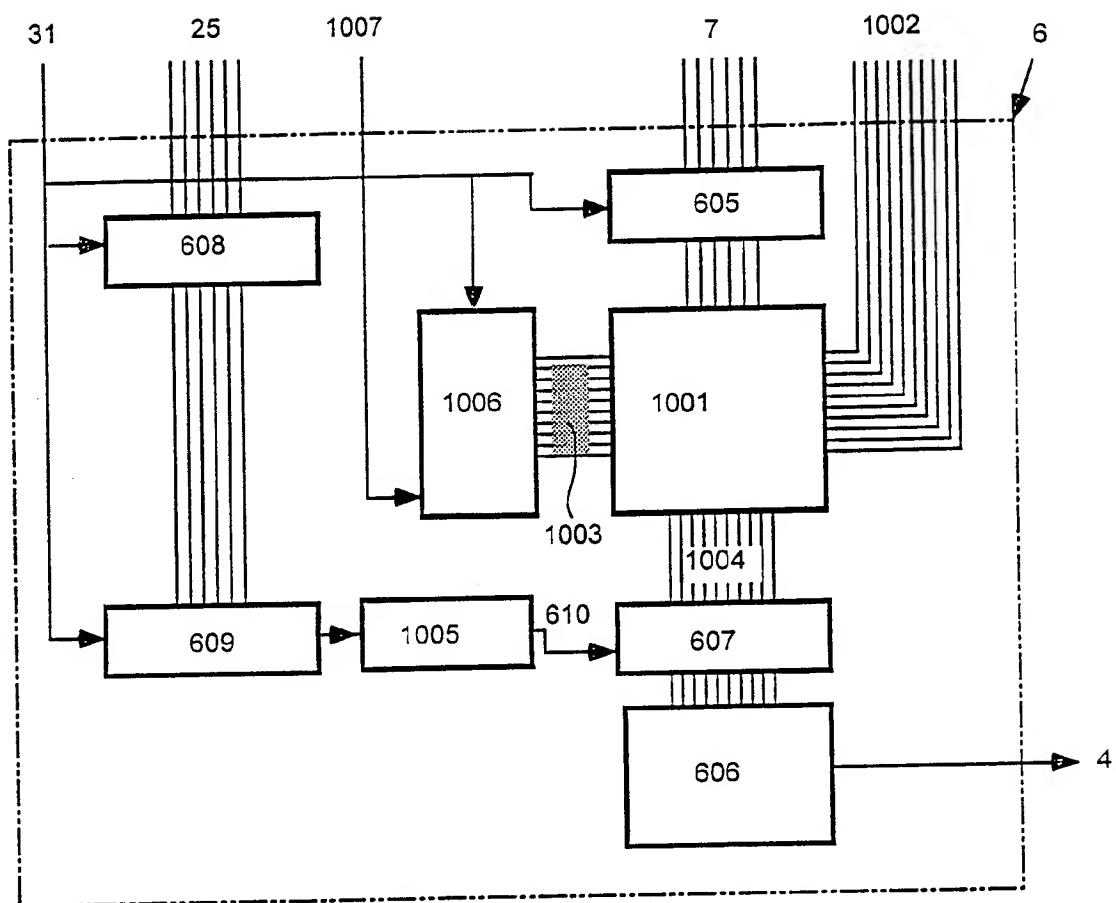
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Fig. 4

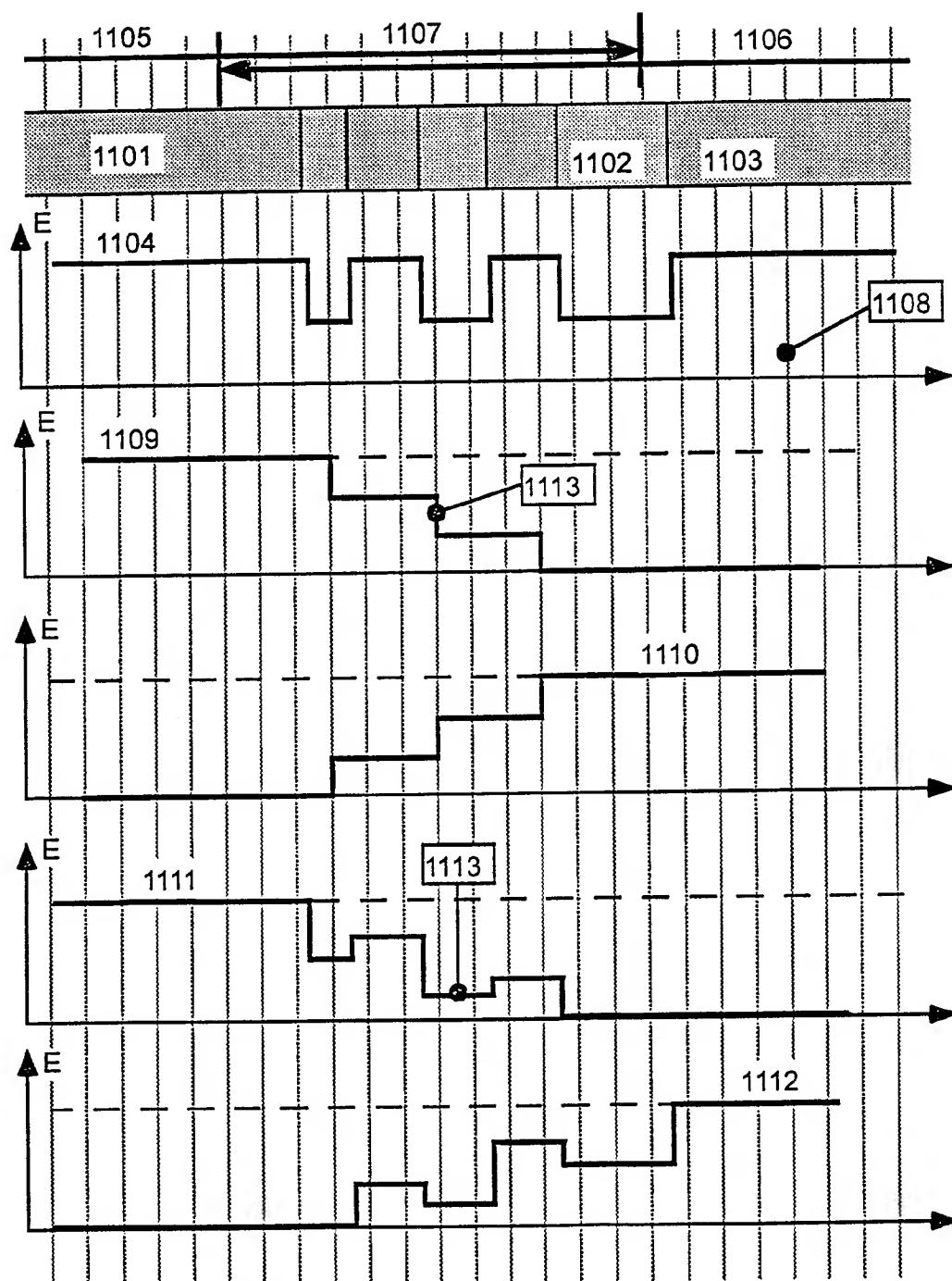Fig. 5

Figure. 6

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Fig. 7

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00134

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G03F 1/08, G03F 7/20
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G02B, G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

QUESTEL: EDOC, WPIL, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5221422 A (SHYAM C. DAS ET AL), 22 June 1993 (22.06.93), claim 1	1-17
	--	
A	WO 9015714 A1 (ANDERSER, ALLAN, VINCENT), 27 December 1990 (27.12.90), claim 1	1-17
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☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	erlier document but published on or after the international filing date	"X"	document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 October 1997	09 -10- 1997
Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Bengt Christensson Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5221422 A	22/06/93	US 4877480 A AT 150555 T CA 2018262 A,C DE 69030215 D,T EP 0404340 A,B JP 3135568 A KR 9407801 B	31/10/89 15/04/97 22/12/90 14/08/97 27/12/90 10/06/91 25/08/94
WO 9015714 A1	27/12/90	AU 5847690 A DK 294189 D	08/01/91 00/00/00